Moving Toward Consistent Analysis in the HFC&IT Program: *H2A*

National Hydrogen Association Meeting

April 26-30, 2004

Preview

- H2A history and purpose
- H2A structure (technical teams)
- Central and forecourt analyses
  - Financial approach
  - Cash flow model
  - Approach to Feedstock / fuels prices
- Delivery analyses
- Accomplishments
- Future plans

History & Where We Are Now

- First H2A meeting February 2003
- Primary goal: bring consistency & transparency to hydrogen analysis
- Current effort is not designed to pick winners
  - R&D portfolio analysis
  - Tool for providing R&D direction

- Current stage: production & delivery analysis - consistent cost methodology & critical cost analyses
- Possible subsequent stages: transition analysis, end-point analysis

- Coordination with: Systems Integration, Program Tech Teams, efforts by H2A team member organizations

H2A Teams

- Central
  - > 50,000 kg/day H_2
  - Johanna Ivy (NREL), Maggie Mann (NREL), Dan Mears (Technology Insights), Mike Rutkowski (Parsons Engineering)
- Forecourt
  - 100 and 1,500 kg/day H_2
  - Brian James (Directed Technologies, Inc.), Steve Lasher (TIAX), Matt Ringer (NREL)
- Delivery
  - Components and delivery scenarios
  - Marianne Mintz (ANL), Joan Ogden (UC Davis), Matt Ringer (NREL)
- Finance, feedstocks, and methodology
  - Marylynn Placet (PNNL)
- Environmental assessment
  - Michael Wang (ANL)

Approach

- Cash flow analysis tool
  - Estimates levelized price of hydrogen for desired internal rate of return
  - Take into account capital costs, construction time, taxes, depreciation, O&M, inflation, and projected feedstock prices
- Production costs estimated
  - Current, mid- (~2015), and long-term (~2030) technologies
    - Natural gas, coal, biomass, nuclear, electrolysis
  - Current delivery components
  - Data from published studies and industry designs
- Refined inputs and results based on peer review and input from key industrial collaborators (KIC)
- Identified key cost drivers using sensitivity analyses

KIC Companies

- AEP
- Air Products
- Areva
- BOC
- BP
- ChevronTexaco
- Conoco Phillips
- Eastman Chemical
- Entergy
- Exxon Mobil
- FERCO
- GE
- Praxair
- Shell
- Stuart Energy
- Thermochem

Questions We Asked of the KIC

- Do the relative costs make sense?
  - Within each technology?
  - Between technologies?
- Are our major assumptions in-line with your experience?
  - Process design
  - Capital costs
  - Performance
  - Feedstock costs
  - Improvements over time
- Do we target the right parameters in our sensitivity analysis?

H2A Cash Flow Analysis Tool

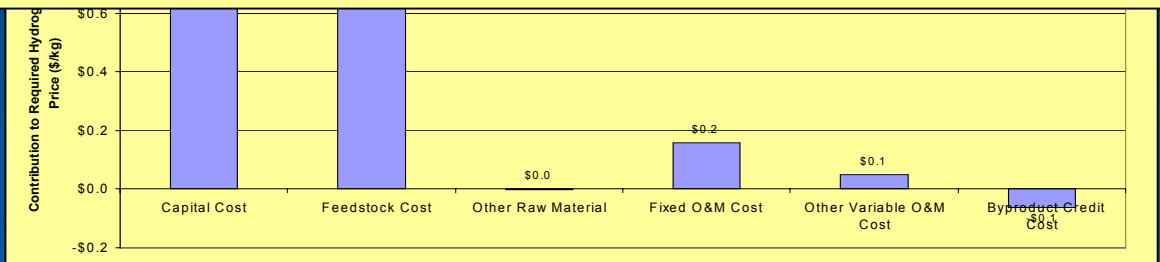
- Process Description
- Feedstock & Utility Prices
- Technology Performance Assumptions
- Process Flowsheet & Stream Summary
- Financing Inputs
- Cost Inputs
- Replacement Capital
- Cash Flow Analysis
- Results - Price of H2

VARIABLE PRODUCTION COSTS (at 100% capacity, startup year dollars)	
	Base Case:
Feedstock Costs	
Type of **electricity** used	none
Escalating **electricity** cost? (Enter yes or no)	Yes
Enter **electricity** cost if NO is selected above ($/kWh)	
Electricity consumption (kWh/kg H2)	
Electricity cost in startup year ($/kWh)	
Electricity cost ($/year, startup year dollars)	$0
Type of **natural gas** used	None
Natural gas energy content, LHV, if standard H2A value is not desired (GJ/Nm3)	0.038
Escalating **natural gas** cost? (Enter yes or no)	Yes
Enter **natural gas** cost if NO is selected above ($/Nm3)	
Natural gas consumption (Nm^3/kg of H2)	0

	Base Case	H2A Guidelines
decade increments)	2000	2000
umed Start-up Year	2005	2005, 2015, 2030
er-Tax Real IRR (%)	10%	10%
CRS, Straight Line)	MACRS	MACRS
ength (No. of Years)	20	20
lysis Period (years)	40	40
Plant Life (years)	40	40
ed Inflation Rate (%)	1.90%	1.90%
e Income Taxes (%)	6.0%	6%
l Income Taxes (%)	35.0%	35%
fective Tax Rate (%)	38.9%	
acity (kg of H2/day)	-	
Capacity Factor (%)	90%	Varies according to case
Output (kg H2/day)	-	
Plant Output (kg H2/year)	-	

Solve Cash Flow for Desired IRR

Hydrogen Selling Price and Cost Contributions (Year 2000 $)	
Required Hydrogen Selling Price ($(Year 2000)/kg of H2)	**$1.886**
Capital Cost Contribution ($/kg of H2)	$0.779
Feedstock cost contribution ($/kg of H2)	$0.642
Fixed O&M (labor etc.) cost contribution ($/kg of H2)	$0.217
Other Variable O&M cost contribution ($/kg of H2)	$0.248
Byproduct credit cost contribution ($/kg of H2)	$0.000



Key Financial Parameters Forecourt and Central

- + Reference year (2000 $)
- + Debt versus equity financing (100% equity)
- + After-tax internal rate of return (10% real)
- + Inflation rate (1.9%)
- Effective total tax rate (38.9%)
- Design capacity (varies)
- Capacity factor (90% for central (exc. wind); 70% for forecourt)
- Length of construction period (0.5 – 3 years for central; 0 for forecourt)
- Production ramp up schedule (varies according to case)
- Depreciation period and schedule (MACRS -- 20 yrs for central; 7 yrs for forecourt)
- Plant life and economic analysis period (40 yrs for central; 20 yrs for forecourt)
- Cost of land ($5,000/acre for central; land is rented in forecourt)
- Burdened labor cost ($50/hour central; $15/hour forecourt)
- G&A rate as % of labor (20%)

Feedstock and Utility Prices

Issues:

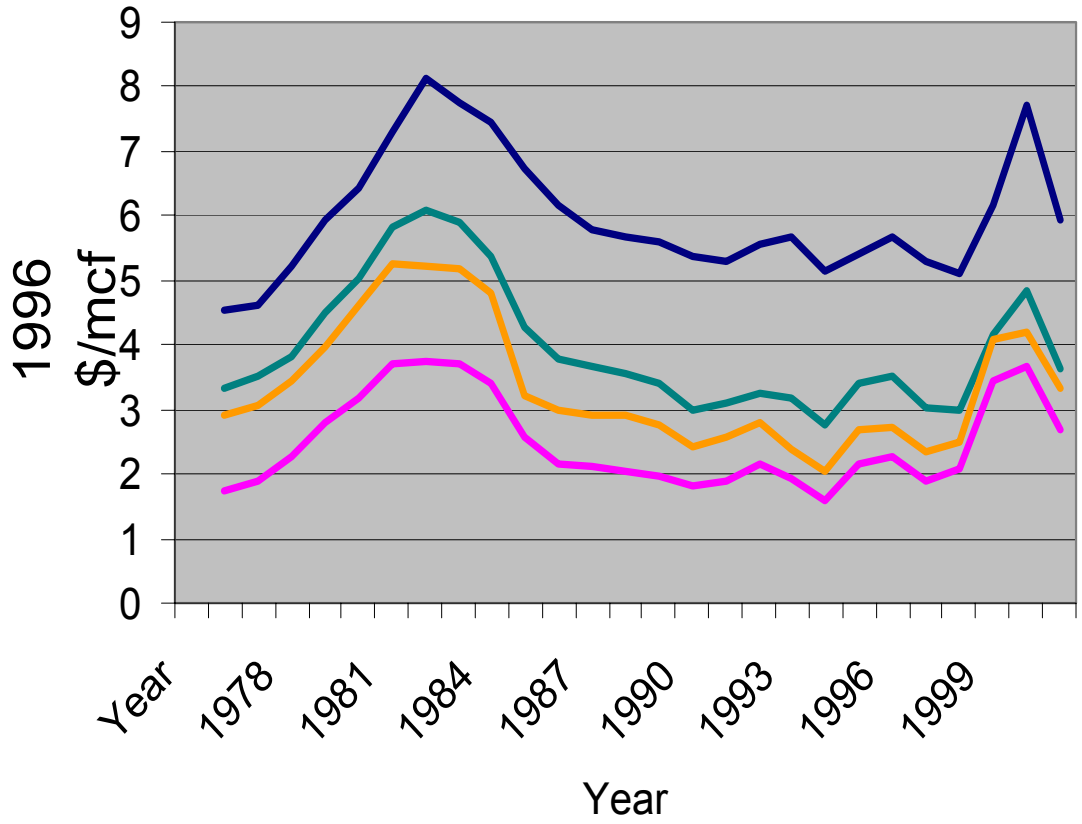
- Future prices of any fuel / feedstock will be dependent on market demand for that fuel / feedstock
- Demand for hydrogen may affect future fuel / feedstock prices
- Delivered prices vary significantly by sector (i.e., commercial, industrial, utility)
- Historically, volatility and risk have varied among fuels / feedstocks
- Prices also vary among locations

Feedstock and Utility Prices, cont.

Solution:

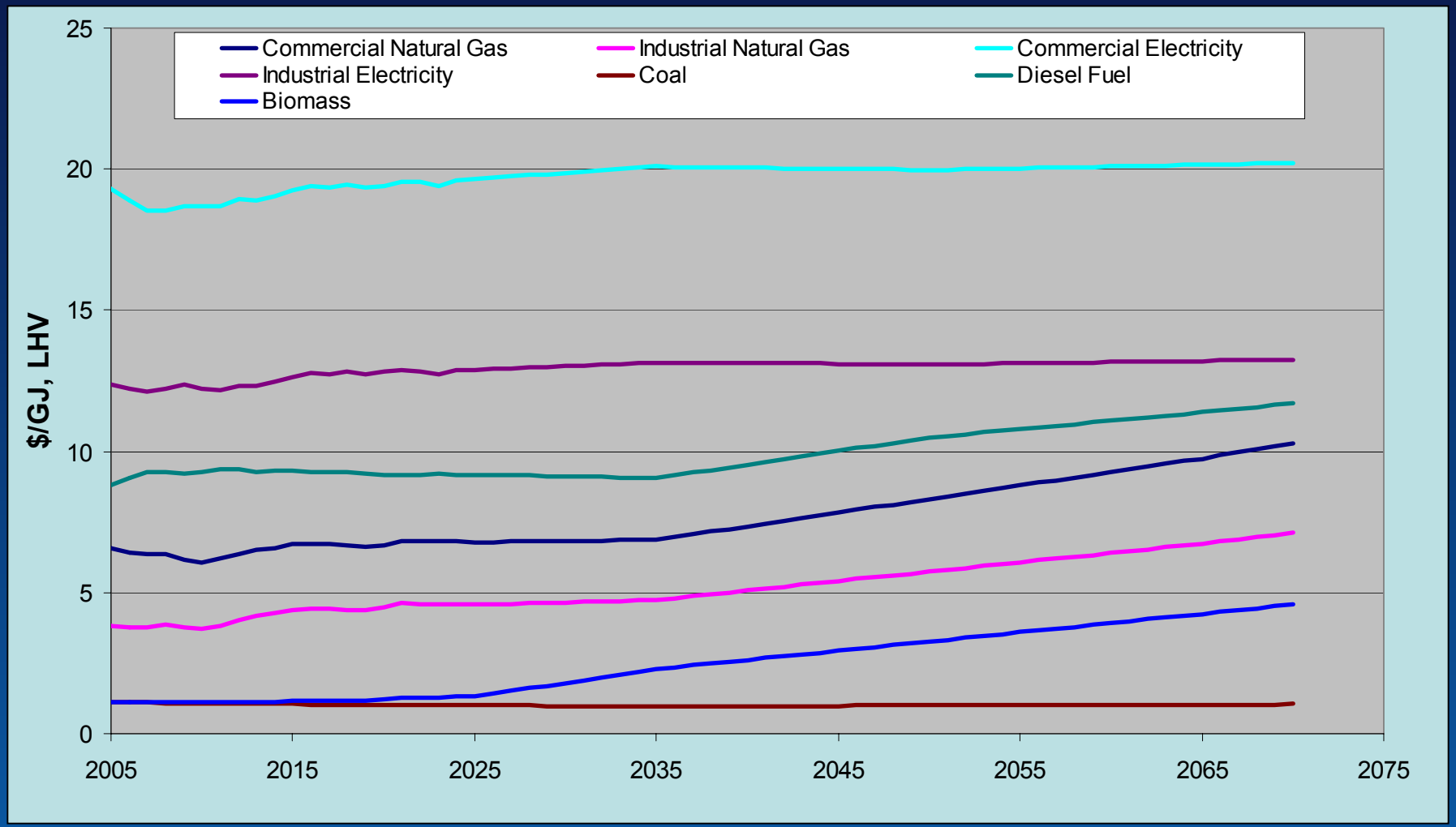
- Develop reasonable price projections
  - Use "official" base case EIA projections through 2025 and extrapolate costs to 2070 using longer-term models (e.g., PNNL's Climate Assessment Model (M-CAM) and MARKAL)
  - Inflate current market prices and apply professional judgment
  - Use national averages to represent generic U.S. cases
- Conduct sensitivity runs to examine the effects of varying the feedstock/energy prices on the hydrogen price

Real Natural Gas Prices (1996 $/mcf)



Source: EIA

Fuel / Feedstock Price Projections



H2A Delivery Analysis

- Develop delivery component cost and performance database
- Develop delivery scenarios for major markets and demand levels
- Estimate the cost of H_2 delivery for scenarios

Assume 2005 delivery technologies

Delivery Scenarios

Market Type	Early Fleet Market (1%)	General Light Duty Vehicles: Market Penetration		
		Small (10%)	Medium (30%)	Large (70%)
Metro	X	X	X	X
Rural			X	
Interstate			X	

Delivery costs are based on component combinations that meet the demands of the market

3 Delivery Modes: Compressed Gas Truck; Liquid H2 Truck; Gas Pipeline

What We've Accomplished

- Developed central and forecourt standard reporting spreadsheets
  - Documents assumptions, inputs, and results
- Completed base cases with sensitivity analysis for current, mid-term, and long-term technologies
  - Natural gas reforming: central and forecourt
  - Coal
  - Biomass
  - Nuclear
  - Central wind / electrolysis
  - Distributed electroysis
  - LH_2 and cH_2 (Tube Trailer and Pipeline) Delivery
- Worked with key industry collaborators (KIC) to establish parameters, process designs, and technology assumptions
- Demonstrated ability to calculate levelized hydrogen price and document a consistent set of assumptions
  - Results are not meant to "select" one technology over another, but to provide R&D guidance

Immediate Next Steps

- Incorporate energy efficiency and environmental measures (Summer ‘04)
- Website with spreadsheet tool, results, and detailed documentation (Summer ‘04)
- Complete delivery component and scenario cost analysis (Fall ’04)
- Complete remaining cases (Fall ‘04)
- Peer-reviewed paper (Fall ‘04)
- Plan for next phase of H2A

Many Many Thanks

- Mark Paster, Pete Devlin, Roxanne Danz – DOE
- Key Industrial Collaborators
- H2A team and their organizations